

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

(NASA-CR-161191) TEST AND EVALUATION OF
FERN ENGINEERING COMPANY, INCORPORATED,
SOLAR HEATING AND HOT WATER SYSTEM (Fern
Engineering Co., Buzzards Bay, Mass.) 24 p
HC A02/MF A01

N79-24438

Unclas
CSCI 10A G3/44 20907

TEST AND EVALUATION OF FERN ENGINEERING COMPANY, INC., SOLAR HEATING AND HOT WATER SYSTEM

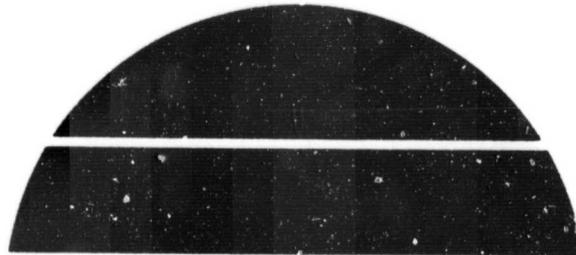
Prepared from documents furnished by

Fern Engineering Company, Inc.
P. O. Box M
Buzzards Bay, Massachusetts 02532

Under Contract NAS8-32246 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy



U.S. Department of Energy



Solar Energy

TABLE OF CONTENTS

SOLAR FLAT PLATE COLLECTOR

- | | | |
|----|-----------------------------|---|
| 1. | Structural Evaluation | 1 |
| 2. | Flame Spread Classification | 4 |
| 3. | Fire Tests | 4 |

ENERGY TRANSPORT MODULE (ETM)

- | | | |
|----|---------------------------|---|
| 1. | Operation Test | 6 |
| 2. | Dielectric Withstand Test | 6 |

CONTROL PANEL

- | | | |
|----|------------------------------|---|
| 1. | Temperature Test | 7 |
| 2. | Over And Under Voltage Tests | 8 |
| 3. | Dielectric Withstand Tests | 8 |

CONCLUSIONS

- | | |
|----------------------|-----|
| Appendix A | A-1 |
| Appendix B | B-1 |
| Appendix C (Deleted) | |
| Appendix D | D-1 |



UNDERWRITERS LABORATORIES INC.

333 PINGSTEN ROAD NORTHBROOK, ILLINOIS 60062

an independent, not-for-profit organization testing for public safety

May 17, 1978

MH10668
77NK6727

RECEIVED

MAY 25 1978

FERN ENGINEERING
BOURNE, MASS.

Fern Engineering Company, Inc.
P. O. Box M
Buzzards Bay, MA 02532

Attention: Mr. P. Levine

Subject: Solar Heating and Hot Water System

Gentlemen:

This will report the results of our investigation to date under Project 77NK6727.

The portions of the system submitted for examination and testing are described in the Appendices to this Report indicated below.

- Appendix A - Solar Flat Plate Collector Panel
- Appendix B - Energy Transport Module
- Appendix C - Control Panel (Deleted)

The test setup for fire tests of the collector panels is illustrated in App. D.

The results of our examination and tests of the portions submitted are as follows:

SOLAR FLAT PLATE COLLECTOR

1. Structural Evaluation -

A. Based on the calculations and information furnished, as well as on our discussions with you, we understand the solar collectors are to be used in the Pennsylvania and Michigan areas and are located about 18 ft from the ground. The design loads used for review of the structural characteristics of the collector, based on loads indicated in ANSI A58.1 (American National Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures) and The BOCA Basic Building Code (BOCA) are the following:

Mil0668
 Page 2
 May 17, 1978

Snow Load = 40 psf
 Wind Load (downward) = 31 psf (90 mph)
 Wind Load (uplift) = 25 psf (0.8 x 31) (Approx)
 Wind Load (suction) = 25 psf (0.8 x 31) (Approx)

B. The snow load of 40 psf, based on a collector width (maximum) of 52 in., results in a uniformly distributed load of 86.7 lb per foot on the aluminum collector frame. The 9.5 in. deep collector frame (shown in Fig. 1, App. A) has its neutral axis located 4.6 in. from the bottom. The five bolts used to connect the portions of the collector are 5/16 in. in diameter, and are of stainless steel material which your calculations assume to have a minimum ultimate stress of 95,000 psi. The resulting moment of inertia and minimum section modulus are 18.77 in.⁴ and 3.83 in.³, respectively. The maximum bending moment due to snow load on the collector with a maximum span of 97.5 in. is 8585 in.-lb. The actual fiber stress is 2242 psi.

Based on publication issued by the Aluminum Association, the allowable fiber stress for 5052-H32 aluminum alloy is 8485 psi, based on a factor of safety of 1.65 and a minimum yield stress of 14,000 psi. For 6061-T6, 6063-T6, and 3003-H14 aluminum alloys, used in various parts of the collector frame, the allowable fiber stresses are 12121, 6666 and 8485 psi, respectively. The actual maximum deflection for the simple supported frame is 0.54 in., based on a minimum modulus of elasticity of 10,000,000 psi.

C. The collector is inclined at an angle of 45 deg to the roof. The collector frame is subjected to wind uplift at the bottom and wind suction at the top resulting in a total upward wind load of 50 psf (based on values of Item A above). The actual fiber stress and deflection based on structural properties indicated under Item B above are 2803 psi and 0.68 in., respectively.

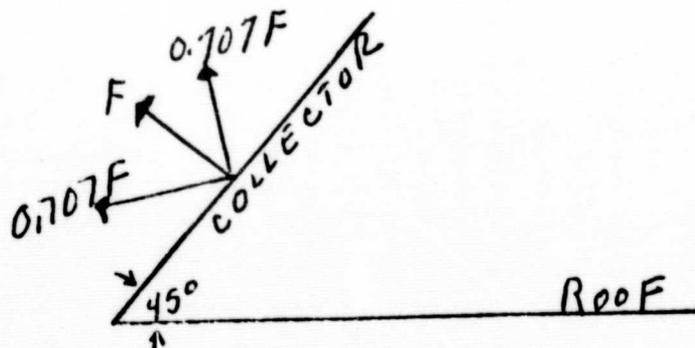
D. The collector cover (glazing) consists of minimum 0.205 in. (nominal 13/64 in.) thick fully tempered glass supported at the four edges by the collector frame assembly. The glazing area of the collector subjected to a wind load of 31 psf or a snow load of 40 psf is 30.67 sq ft. The allowable wind load for fully tempered glass, based on Tables 857.5.4.1 and 857.5.4.2 shown in BOCA is 92 psf.

Mh10668
 Page 3
 May 17, 1978

E. The wind and snow loads result along the long axis of the collector in a bearing load of 87 lb per lineal foot on the gasket. The corresponding design bearing stress on the rubber channel is 16 psi. The small scale test results furnished by the manufacturer indicate a compression or bearing stress of 100 psi at 0.050 deflection.

F. The total upward force on the collector is 50 psf (from Item C above). The illustration below indicates the normal and axial forces on the roof system. The total upward force (F) on the 52 in. by 97.5 in. collector is 1760 lb. Therefore, we believe the normal (vertical) and horizontal (axial) forces on each of the two supports used to secure the collector to the roof system are 880 lb.

Thus the truss system is subjected to a bending moment of $880 \times 30 = 26400$ in.-lbs from the horizontal component of the load acting on the collector whose center is located 30 in. above the roof truss system. The 11 gauge steel bracket, indicated in Fig. 2, App. A is fastened to the collector with four 1/4 by 3 in. lag screws. Since the axial load on each of the two brackets is 880 lb, the lag screws are capable of withstanding the imposed axial load. However, the vertical load imposes an additional moment depending on the location of the collector, location of the supports and the structural properties of the truss system which are not know to us. Therefore, the fastening system used to attach the collector system to the roof and the adequacy of the roof system itself in resisting the loads have not been reviewed as part of this investigation.



MH10668
 Page 4
 May 17, 1978

2. Flame Spread Classification -

The rear cover insulation consisted of 3/8 in. thick material designated as "Thermal Insulation Wool Type II" and is manufactured by Owens-Corning Fiberglas Corporation and is reported by Fern Engineering as having a Flame Spread Classification of 21 and Smoke Developed Classification of 0. The sides of the collector, between the copper absorber plate and the glass cover, consist of 1 by 1-3/4 in. insulation board material designated as "TF-400" and is manufactured by Celotex Corporation and is reported by Fern Engineering as having a Flame Spread Classification of 20 and Smoke Developed Classification of 30. The insulation materials did not bear the Listing Mark of Underwriters Laboratories Inc. or evidence that it has been tested by any other nationally recognized laboratory.

3. Fire Tests -

A. The construction of the collector system or the identification of materials or components used in the collector were not observed by personnel of the Laboratory. Class A Burning Brand and Intermittent Flame tests were conducted on representative collector panels mounted on test decks which consisted of 1/2 in. thick plywood panels covered with UL Labeled Class A asphalt glass mat shingles. The wind velocity in these tests was 12+1/2 mph as specified in Standard UL790 (Tests for Fire Resistance of Roof Covering Materials). Fig. 1, App. D shows the appearance of the test set-up for the Burning Brand Test. The positioning of the solar panel on the shingled deck was the same for the Intermittent Flame Test as indicated by the side view for the Burning Brand Test.

B. For these tests, the shingled deck described in Item A was mounted on the test carriage at an incline of 3 in. to the horizontal foot and a 4 by 8 ft solar collector panel was mounted on the deck using wood blocks and sections of 2 by 4's for support. The lower end of the panel was 1-1/2 in. above the shingled deck and 12 in. back from the leading edge and rested on 2 by 4 in. blocks to which were nailed 1 by 3 in. retaining

MH10668

Page 5

May 17, 1978

blocks (to prevent the panel from sliding down). The back or higher end of the panel was supported by 6 in. long blocks to position the 4 ft dimension of the panel at an incline of 2 in. to the horizontal foot with relation to the shingled deck which was mounted at a 3 in. incline. Accordingly, overall, the solar panel was mounted at an incline of 5 in. to the horizontal foot.

C. In the Burning Brand Test, a Class A brand, weighing 1968 grams was ignited for 5 min in a gas flame and placed on the glass surface of the panel with the lower end resting against the aluminum flange - as would be the case if the brand landed on the panel and slid down to that point. At 1 min, 25 sec, the entire glass surface shattered and the brand fell into the area beneath the glass and rested on the copper sheet. When the glass shattered, shards of glass (10 in number) were projected to the floor about 2 to 3 ft away from the carriage. About 30 shards were noted on the shingled surface of the test deck and the mock eave of the test carriage. At 10 min:15 sec, the brand was one-half consumed and the copper sheet in the brand area was cherry red. At 20 min:45 sec, the brand was 90 percent consumed and the cherry red glow of the copper sheet was diminishing in intensity. At 25 min, only very light flaming of the few remaining brand coals persisted and the glow had disappeared. All action ceased at 29 min:30 sec, with no penetration observed on the bottom side of the solar panel.

D. For the Intermittent Flame Test, another panel was mounted in the same manner as described above for the Burning Brand Test and subjected to the application of the Class A test flame as described in Standard UL790. During the first application of the test flame, it was noted that flame impingement on the shingles and the solar panel was poor. A 2 by 4 block about 3 ft long was placed an angle across the right side asbestos cement board baffle and the mock eave and this improved impingement considerably. No ignition of the shingles occurred until the third application and, from that point on, there was only minimal flaming of the shingles with no visible action noted on the solar panel after 15 applications of the test flame.

MJ110668
Page 6
May 17, 1978

E. Observations made during these tests indicated that the solar panel had no adverse effect on the performance of the shingles. The shingles continued to provide protection to the plywood deck and prevented underside ignition.

ENERGY TRANSPORT MODULE (ETM)

1. Operation Test -

The sample ETM was electrically connected to the remote control panel which was supplied with a 120 v ac potential, and Terminals TBI-1, -2, -3 and -4 of the control panel were jumpered to simulate Mode 1 or direct solar heating operation (end dampers, Nos. 1 and 4 open, center dampers No. 2 and 3 closed). The outlet for solar heating (blower end) was connected by duct work to a nozzle flow chamber. The system was set in operation against an external static pressure of 0.40 in. WC until steady state conditions of air flow and equilibrium temperatures were achieved. The results are as tabulated below:

Electrical Potential - 120 v ac
Motor Current Draw - 3.2 amp
Room Temperature - 76 F
Motor Winding Temperature - 179 F (+)
External Static Pressure - 0.40 in. WC
Air Delivery Rate - 611 CFM (++)

(+) - Resistance method.
(++) - Air delivery corrected for standard air density of 0.075 lbm/cu ft.

2. Dielectric Withstand Test -

Immediately following the operation test a 60 Hz potential of 1000 v was applied for 1 min between high voltage live parts and dead-metal parts of the ETM. The potential was withstood without breakdown.

MH10668
 Page 7
 May 17, 1978

It should be noted that two prior attempts were made to operate the ETM under rated conditions without success. The original drive pulley was 3-1/4 in. in diameter, for which you sent a 3-3/4 in. diameter replacement. The new pulley (adjustable) was installed and adjusted for the maximum pitch diameter. Stable operation still was not obtainable and it was discovered that the pulley was defective allowing the spokes of the driven pulley to rotate with respect to the hub to which they are staked. An identical undamaged pulley was found and used for the test outlined above.

CONTROL PANEL

1. Temperature Test -

The control panel was mounted on a vertical wall and Terminals TB1-1, -2, -3 and TB1-5 and -6 were jumpered to simulate "heating from storage" (Mode 2). This mode was selected since the maximum number of relays are energized. The inlet damper motor of the ETM was connected across Terminals TB2-6 and -9 and the motor across TB2-8 and -9. A 120 v ac, 16 amp external source was connected across Terminals TB3-3 and -4 to represent the largest remote fan motor load the Relay 4 contacts are rated for and a 5 amp load was connected across terminals TB2-1 and -2 to simulate the heating water pump load. The following temperatures were recorded (1) with the above loads connected (first column) and (2) with all controlled loads disconnected (second column).

<u>Thermocouple Location</u>	<u>Maximum Recorded Temperature Degrees F</u>		<u>Maximum Allowable Temperature Degrees F</u>
	<u>With Load</u>	<u>Without Load</u>	
Room	79	76	-
Control Box Ambient Near Top	127	115	-
Relay K4 Coil	220	115	196
Relay K5 Coil	250	244	196
Relay K6 Coil	229	224	196
Control Transformer Coil	223(+)	-	232

(+) - Change of resistance method.

The temperatures of relay coils energized for the test exceed the maximum allowable temperatures (Column 3).

MH10668
Page 8
May 17, 1978

2. Over And Under Voltage Tests -

Following the above test the supply voltage to the control panel was increased to 132 v and maintained until the coils of the relays reached constant temperature. The supply circuit potential was then reduced to 120 v and the relays were found to operate as intended. Following this, the supply circuit potential was maintained at 120 v until the coils reached a constant temperature. Then the supply circuit potential was reduced to 102 v and it was observed that the relays operated as intended at the reduced voltage.

3. Dielectric Withstand Test -

Immediately following the temperature test a 60 Hz potential of 1240 v was applied for 1 min between high voltage live parts and dead-metal parts and 500 v for 1 min, between high voltage parts and low voltage parts. The potentials were withstood without breakdown.

CONCLUSIONS

1. Based on our review, the solar collector is capable of withstanding a snow load of 40 psf, wind load (downward) of 31 psf, uplift wind load of 25 psf and suction wind load of 25 psf. The collector meets the requirements indicated in Standard UL790 for the Burning Brand (Class A) and Intermittent Flame (Class A) tests. The alternate frame design incorporating rivet rather than weld joints was not evaluated. Also, the fastening system used to secure the collector panels to the roof and the adequacy of the roof system to resist the additional loads have not been evaluated.

2. Based upon our review the ETM is capable of rated air delivery. The suitability of the heat exchanger has not been evaluated since it is not evident what maximum water temperatures can be expected in the system (see our comments below regarding the differential controller).

3. The results of our tests of the control panel indicate that the relay coil temperatures exceed the temperature limits allowed for the insulating materials involved. We have the following additional comments regarding the control system:

MH10668

Page 9

May 17, 1978

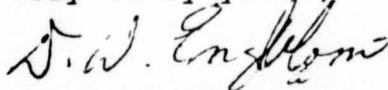
A. In our interim Report dated August 19, 1977 it was indicated that the differential controller you were considering at that time was not Listed or Recognized. We have not been informed of the name of the manufacturer or model number of the controller you are presently considering. It should be noted however, that your specifications call for a controller which will act to shut off the ETM blower and storage pump motors when storage water temperatures reach 180 F. It appears that if the control is necessary for preventing unsafe temperatures the controller, temperature sensor and interconnecting wiring would have to meet safety device and circuit requirements. We have not investigated this aspect of the design.

B. The wiring diagram secured to the cover of the control panel indicates that a "furnace discharge t'stat" should be connected across Terminals TB1-2 and -3. There are no specifications as to what that device should be. Since safe performance of the system may depend on proper functioning of this thermostat, it should be specified that this be a control which has been investigated under the Standard for Limit Controls, UL353. Also, since this is to be considered a safety circuit (simultaneous solar and auxiliary heating must be prevented, as covered in our letter referenced above) all wiring should be in accordance with requirements for Class 1 circuits. Low-voltage room thermostats normally do not have provisions for Class 1 wiring systems.

We are closing Project 77NK6727 with this Letter Report, in accordance with your letter dated March 15, 1978 and our Accounting Department will prepare and submit an invoice for the charges incurred under this Project.

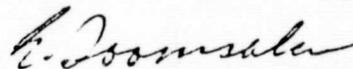
Should you have any questions relative to the above, please let us know.

Very truly yours,



D. W. ENGBLOM
Project Engineer
Heating, Air Conditioning
and Refrigeration Department

Reviewed by:



E. TOOMSALU
Associate Managing Engineer
Heating, Air Conditioning
and Refrigeration Department

A P P E N D I X ADEVICE:

Solar collector panel.

GENERAL:

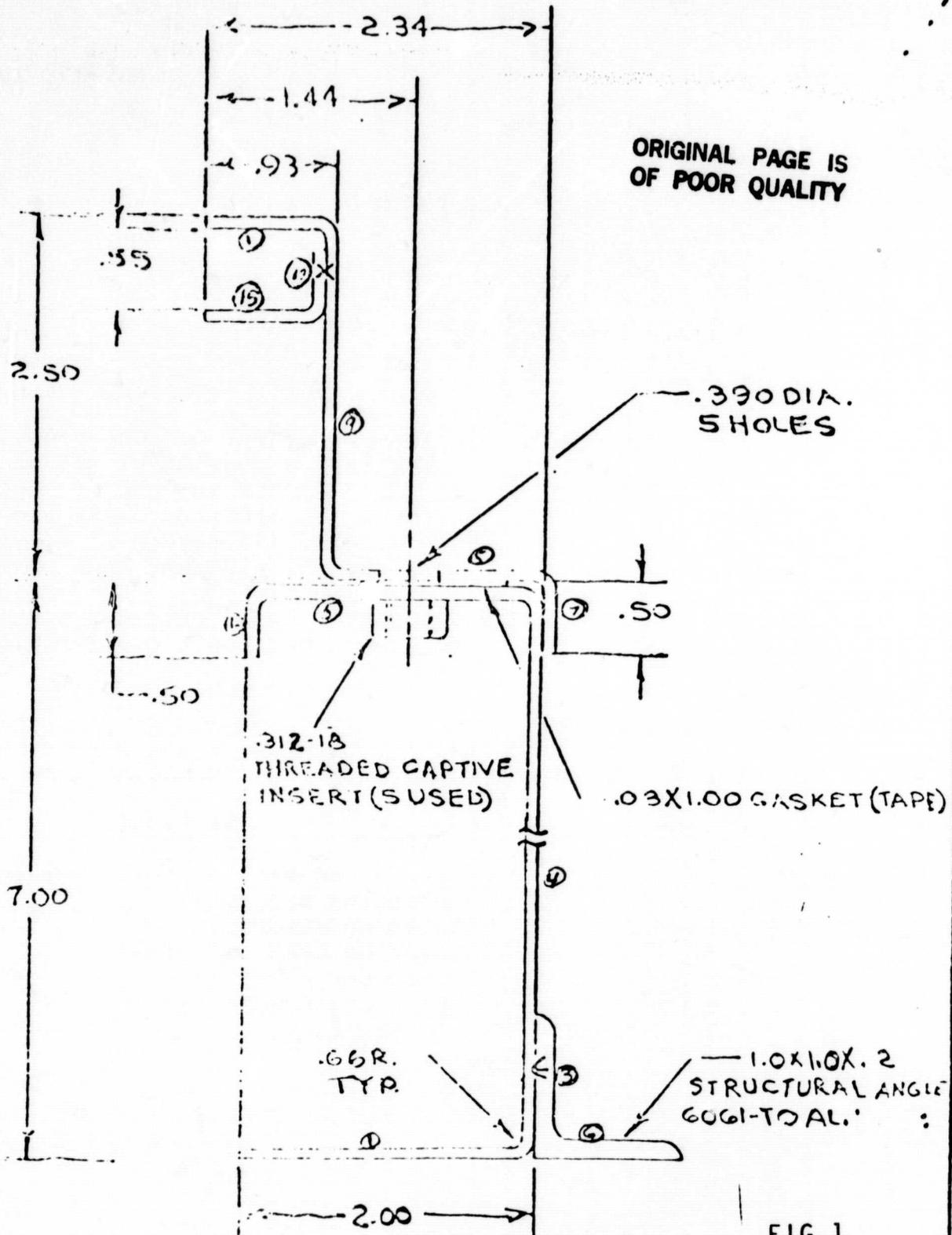
The collector panel is a multilayer component nominally 4 by 8 ft by 9 in. deep. The layers consist of (1) an outer glazing of tempered glass, (2) absorber surface of copper with black chrome selective surface, (3) aluminum ducts and turning vanes to provide two passes of air, (4) layers of fiberglass blanket and insulation board and (5) aluminum back board.

The assembly is held together by an extruded aluminum frame with separable batten which carries the outer glazing member.

CONSTRUCTION DETAILS:

The following figures describe the construction.

<u>Figure</u>	<u>Description</u>
1	Frame and batten cross sections
2	Mounting bracket
3	Glazing material
4	Glazing seal material
5	Absorber material
6	Back board material
7	Panel assembly



ORIGINAL PAGE IS
OF POOR QUALITY

MATERIAL: .03 THICK 5052-H32 AL ALLOY.
X DENOTES SPOT WELDS

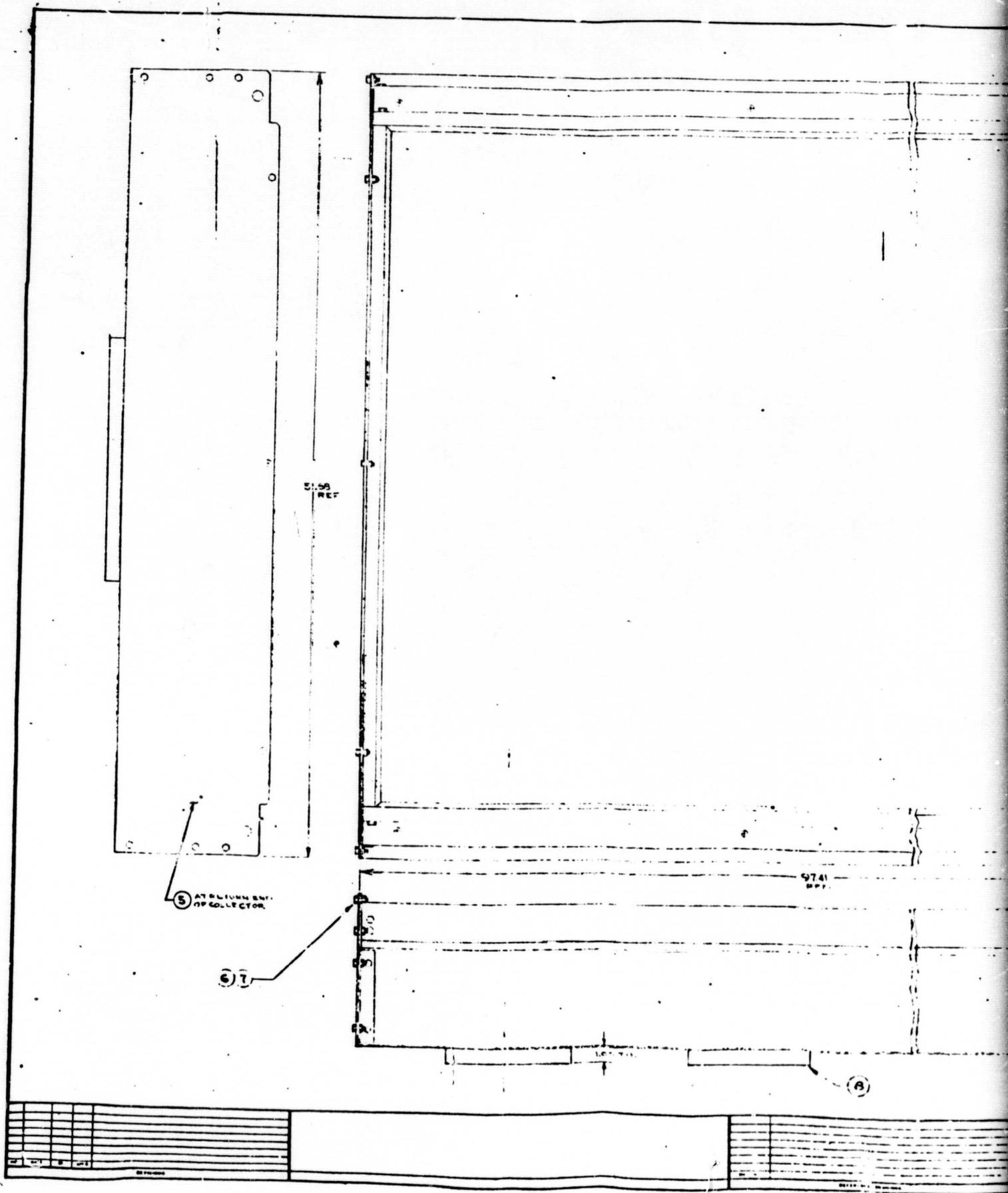
FIG. 1
APP. A
MH 10668

FERN ENGINEERING
BURLINGTON, MASSACHUSETTS
U.S.A.

CRASH
NPD
8

NO
A-2





WELDOUT FRAME /

ORIGINAL PAGE IS
OF POOR QUALITY

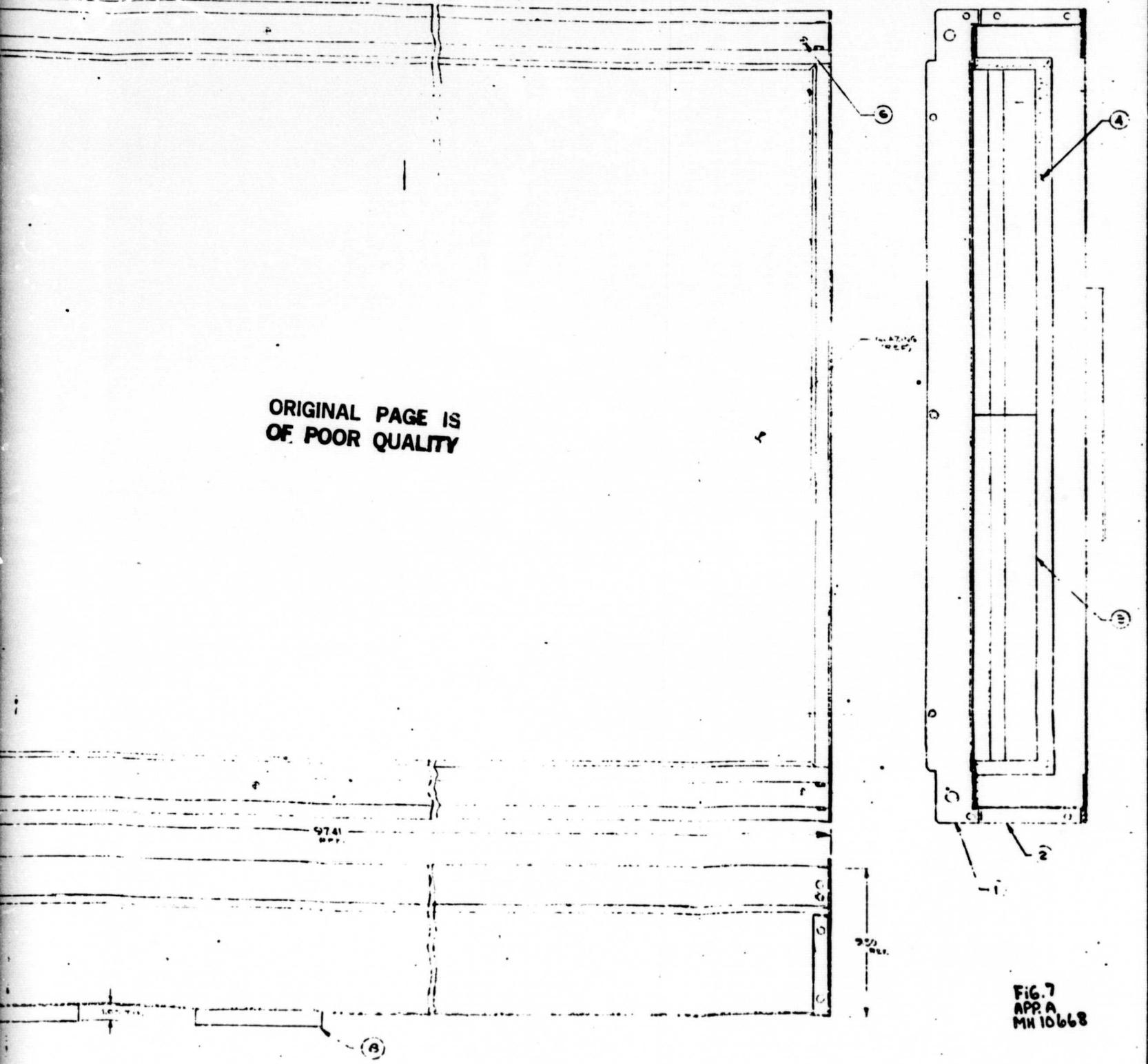


FIG. 7
APP. A
MH 10668

REVISIONS	NO. 1	DATE	BY	APPROVED
FERN ENGINEERING DUFFIELD WAY MASSACHUSETTS U.S.A.		SOLAR COLLECTOR ASSEMBLY TYPE A		A
194.55-A 701				

FOLDOUT FRAME 2

Vendor

ASG Industries
P. O. Box 929
Kingport, Tenn. 37662

Manufacturers

ASG Industries

Material:

Low Iron (.01% iron oxide) fully tempered glass
(Sundex "A" rolled glass)

Size:

.215" ± .010 thick x 45" ± 1/16" wide x 96" ±
1/16" long (weight 8.4#/panel)

Load & Weirps

1/32" over 12" span

Conditions:

Tempered, design strength 6400 psi (Fed Spec DD-G-1403b)

Surfaces:

Horizontally Tempered, semi-round ground edges

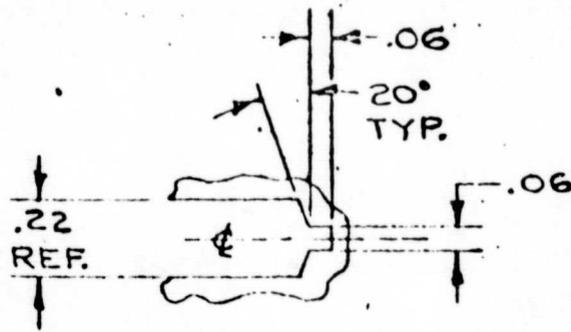
Transmission:

90% of solar energy

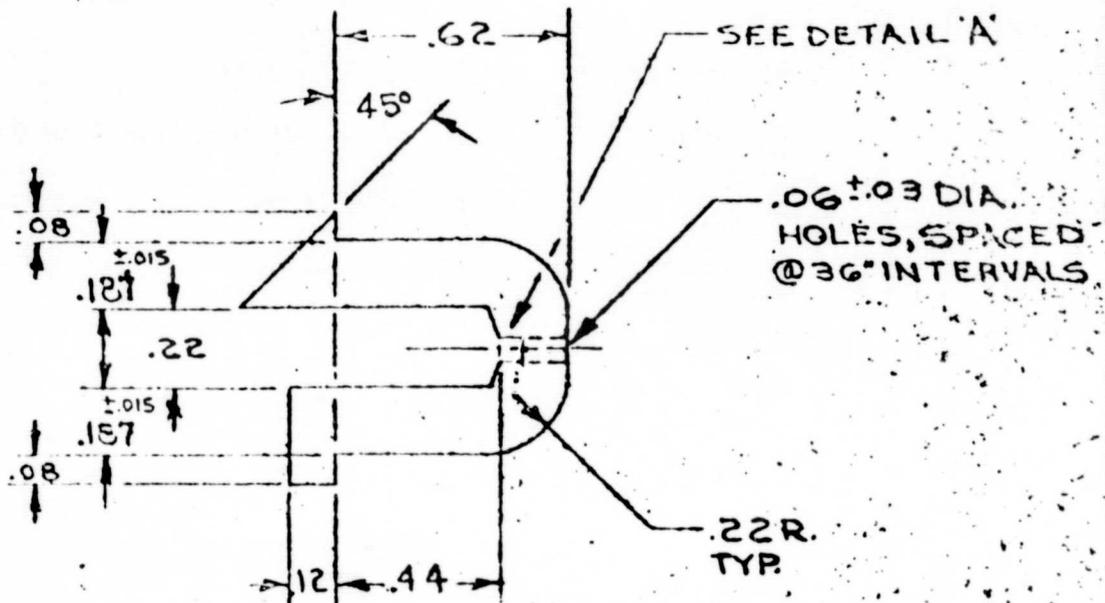
ORIGINAL PAGE IS
OF POOR QUALITY

2
FIG. 3
APP. A
MH 10668

FERN ENGINEERING CURZARD DAY, INC. SACONNETTS UCA A-4	DATE	Specification for Low Iron Glass Glazing	REV.
	DATE		
		DWG. NO. 198-55-F 013	



DETAIL A
SCALE: 2X



NOTES:

SCALE: 2X

1. MAKE FROM GRAY 50 DUREOMETER SILICONE RUBBER, 500°F, RATED
2. TOLERANCES $\pm .031$ EXCEPT WHERE OTHERWISE SPECIFIED.

FIG. 4
APP. A
MH 10668

<p>V.A.S.A. FERN ENGINEERING ROXBURY BLDG., MASSACHUSETTS U.S.A.</p>	<p>DDL J.D. DWA 4/8/77</p>	<p>RUBBER CHANNEL DWA NO 198-55-FO14</p>	<p>✓</p>
--	--	--	----------

Vendor: Barry Solar Products

Manufacturer: Barry Solar Products
Woodbridge at Main
P. O. Box 327
Edison, NJ 08817

Material: Make from 0.0028" thick #110 copper alloy 24" wide.

Process: Apply black chrome selective surface. Surface emmissivity = .10 max., absorptivity = .93 minimum.

Forming: Apply "Oxford Pattern", a $.050^{+0.010}$ offset embossment pattern of a hexagonal arrangement of spherical segments, repeating within 1/2 inch. The "prime side" (convex side) of the pattern shall be embossed on the plain copper side of the material, while the secondary (concave) surface shall be embossed onto the black chrome side.

Length: Orders for less than 200 L.F. (400 SF) shall be completed by the shipping of a single coil. Orders in excess of 200 ft. shall be completed by shipping of coils no shorter than 100 ft., nor longer than 200 ft.

Packaging: Coils are to be rolled onto 16" I.D. cardboard cores, interleaved with heavy paper or air cushioned plastic packaging sheet.

Coils shall be encased in reinforced cartons or crated to avoid damage during shipping.

FIG.5
APP.A
MH 10668

6/10/77 DWG. NO. WAS 198-55-C001

FERN ENGINEERING
SUTHERLAND BLDG., MASSACHUSETTS
USA A-6

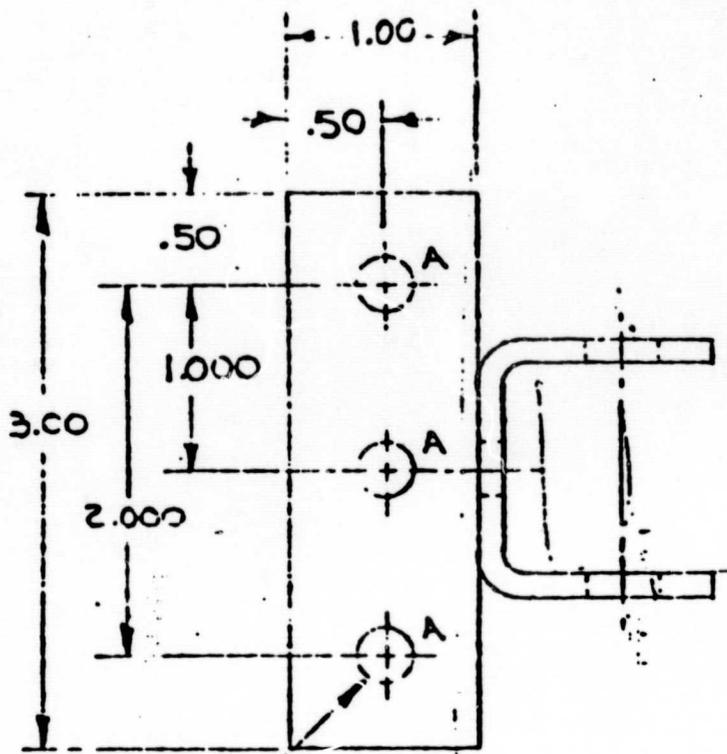
KM
ARD
DWG

Specification For
Absorber

DWG. NO. 198-55-D003

REV. A

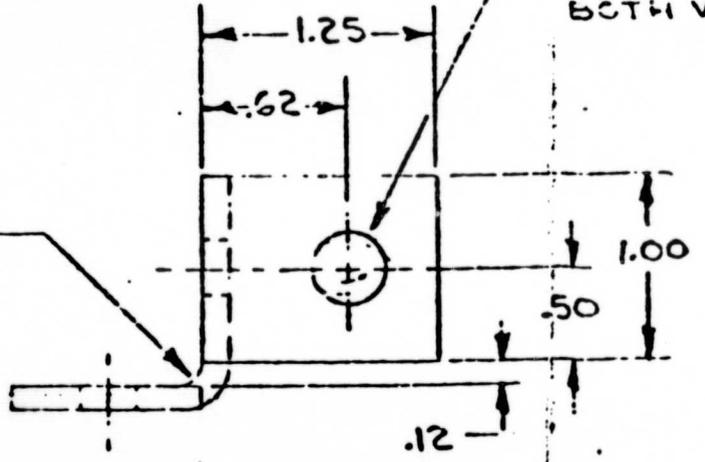




.281 DIA.
4 A HOLES

.12 R.
TYP.

.377 DIA. 2
LINE DRILL
BOTH WALL



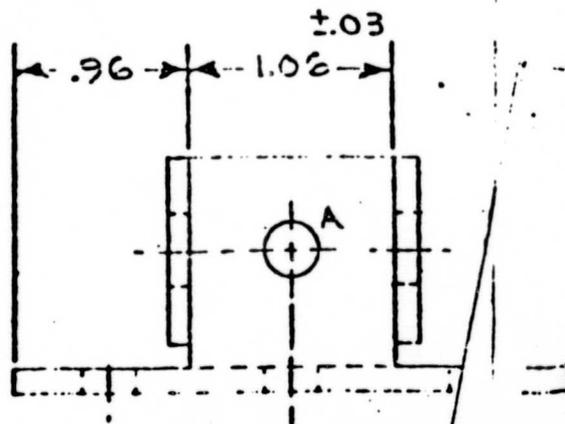
MATERIAL: 11 GA.

FOLDOUT FRAME /

NO.	DATE	REVISIONS	DRAWING	REFERENCE DRAWINGS

FOLDOUT FRAME 2

.375 DIA. 2 HOLES
LINE DRILL THRU
BOTH WALLS



MATERIAL: 11 SA STEEL (.120 THICK)

FIG. 2
APP. A
MH 10668

FERRI ENGINEERING
BUZZARDS BAY, MASSACHUSETTS
U.S.A.

DRAWN
T.O.L.
AP'D
DATE
1/17/75

ROOF MOUNTING
COLLECTOR BRACKET

DWG. NO. SK198-61

REV.

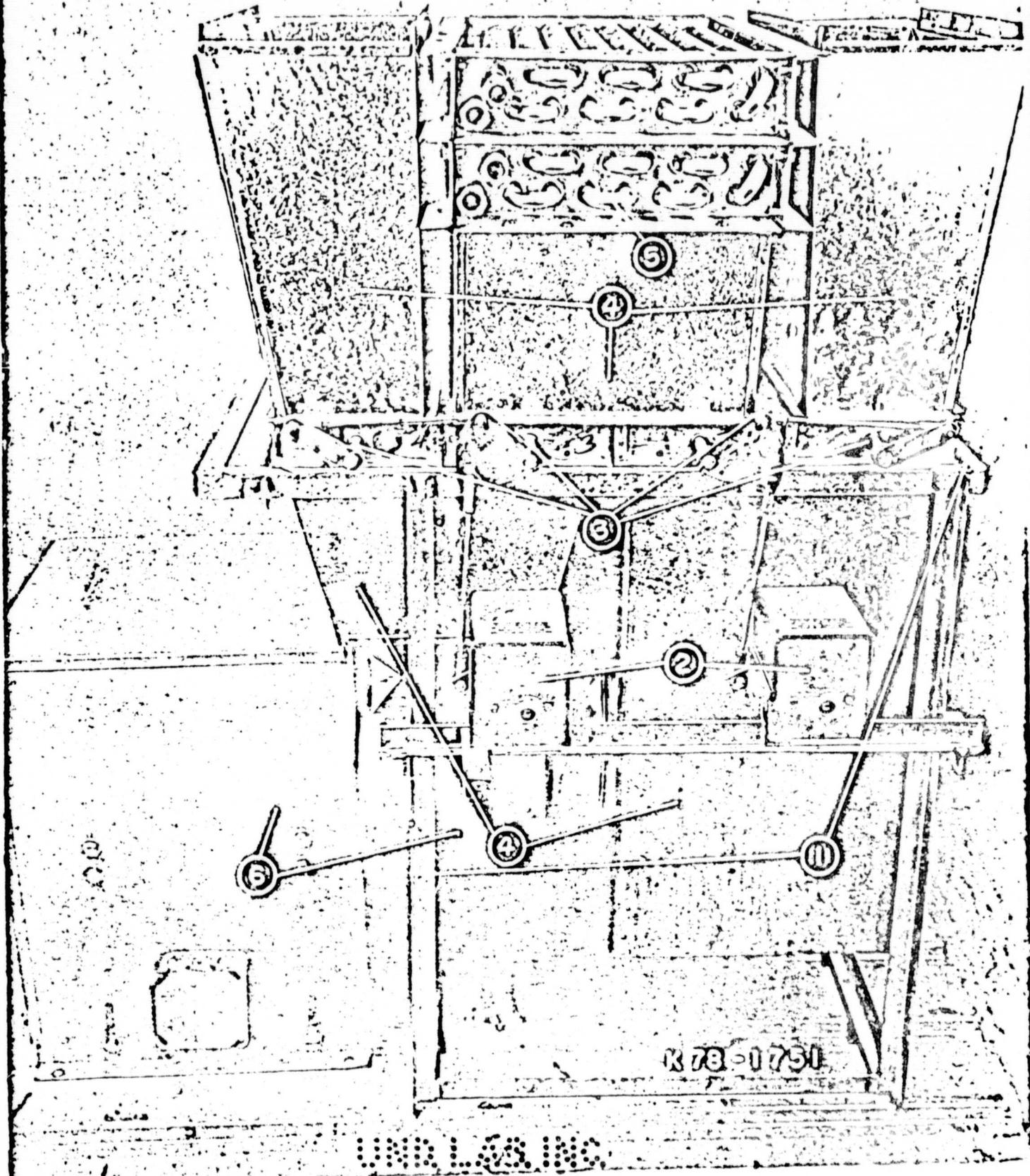


ORIGINAL PAGE IS
OF POOR QUALITY

WH 10338

APP. B

FIG. 1



R 78-1751

A P P E N D I X D

Figure 1 illustrates the orientation of the solar collector panel for the fire tests and the relative location of the fire brand.

MH 106
1-73

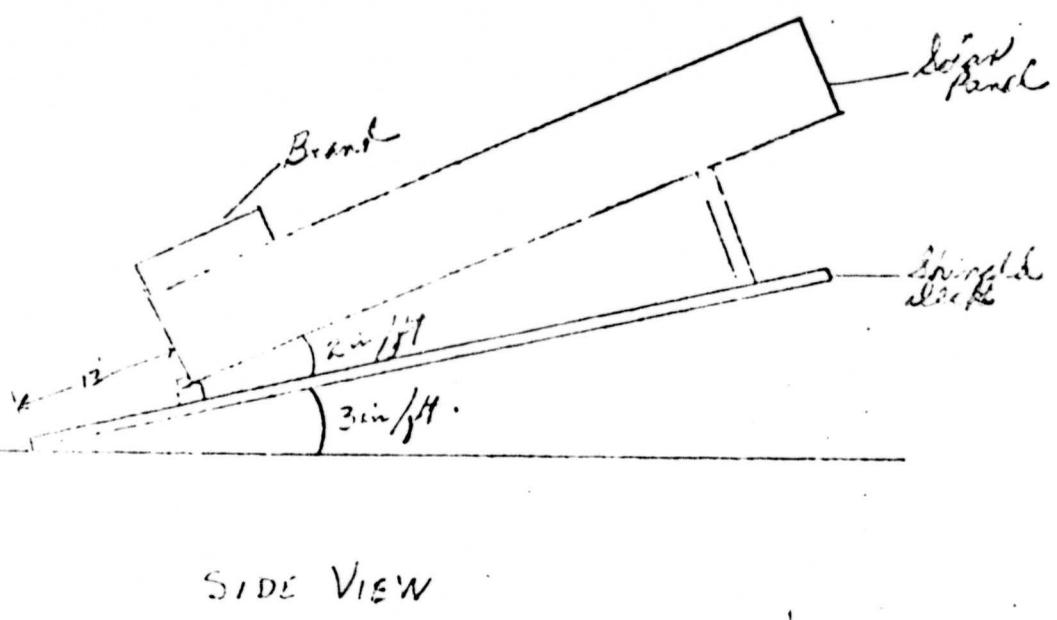
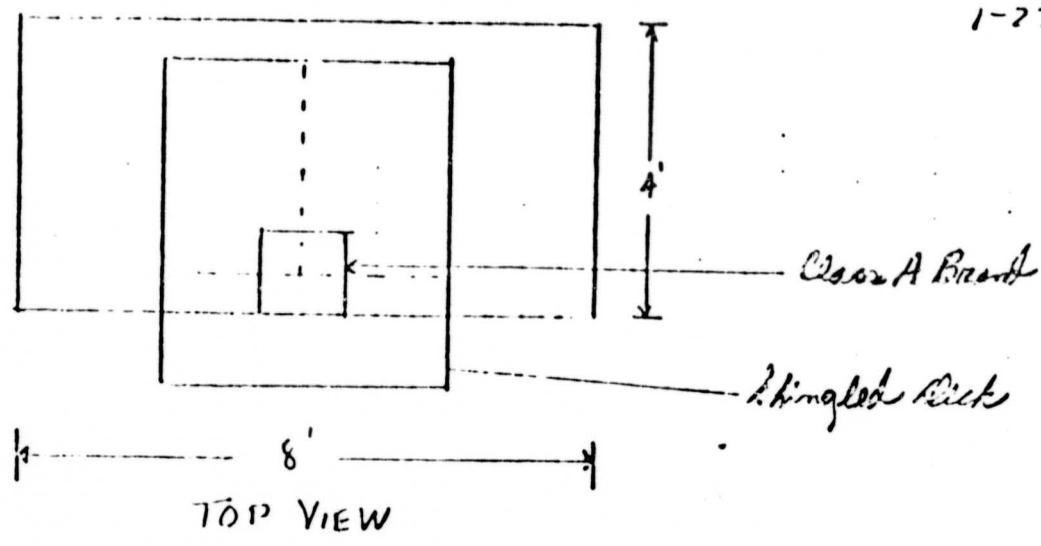


FIG. 1
APP. D
MH 10668